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Effects of Organic Amendments on Productivity and Profitability of Bell Pepper–French Bean–Garden Pea System and on Soil Properties during Transition to Organic Production

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*A transition period of at least 2 years is required for annual crops before the produce may be certified as organically grown. There is a need to better understand the various management options for a smooth transition from conventional to organic production. The purpose of this study was to evaluate the effects of different organic amendments and biofertilizers (BFs) on productivity and profitability of a bell pepper–french bean–garden pea system as well as soil fertility and enzymatic activities during conversion to organic production. For this, the following six treatments were established in fixed plots: composted farmyard manure (FYMC, T_1); vermicompost (VC, T_2); poultry manure (PM, T_3) along with biofertilizers (BF) [*Rhizobium/Azotobacter *+ phosphorus solubilizing bacteria (*Pseudomonas striata*)]; mix of three amendments (FYMC + PM + VC + BF, T_4); integrated nutrient management (FYMC + NPK, T_5); and unamended control (T_6). The yields of bell pepper and french bean under organic nutrient management were markedly lower (25.2–45.9% and 29.5–46.2%, respectively) than with the integrated nutrient management (INM). Among the organic treatments, T_4 and T_1 produced greater yields of both bell pepper (27.96 Mg ha^{-1}) and french bean (3.87 Mg ha^{-1}) compared with other treatments. In garden pea, however, T_4 gave the greatest pod yield (7.27 Mg ha^{-1}) and was significantly superior to other treatments except T_5 and T_1. The latter treatment resulted in the lowest soil bulk density (1.19 Mg m^{-3}) compared with other treatments. Similarly, soil organic C was significantly greater in all the treatments (1.21–1.30%) except T_2 compared to T_6 (1.06%). Plots under INM, however, had greater levels of available nitrogen–phosphorus–potassium (NPK) than those under organic amendments. T_1 plots showed greater dehydrogenase and acid phosphatase activities compared with other treatments. However, T_4 and T_5 plots had greater activities of β-glucosidase and urease activities, respectively. The cost of cultivation was greater under organic nutrient management (except T_2) compared with INM. The latter treatment gave greater gross margin and benefit/cost (B/C) ratio for all vegetables, except that T_2 gave greater B/C ratio in garden pea compared with other treatments. We conclude that T_1 and T_4 were more suitable for enhancing the productivity of bell pepper–french bean–garden pea system, through improved soil properties, during transition to organic production.*

Keywords Bell pepper, economics, french bean, garden pea, organic farming, soil fertility, transition

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Introduction

The concept of organic agriculture is receiving increased attention, and organic food markets are also expanding rapidly in many countries, including India. According to the latest survey, India ranks seventh with about 1.03 million ha land under organic management (Willer and Kilcher 2009). Agriculture in the hills of Uttarakhand has largely remained organic by default. For many (especially small and marginal) farmers, the purchase of manufactured fertilizers and pesticides is and will continue to be constrained by their high costs relative to output prices and risks or simply by unavailability. Furthermore, systems that depend upon sustainable use of locally available natural resources and farmers' knowledge and labor are far more likely to meet the needs and aspirations of resource-poor farmers than those that require costly or scarce external inputs (Parrott, Olesen, and Hogh-Jensen 2006). As productivity of traditional systems in hills is often very low, organic agriculture could provide a solution to the food needs of poor farmers while relying on natural and human resources. Presently, about 35,000 organic farmers are registered with Uttarakhand Organic Commodity Board. The registered farmers are currently motivated mainly by the expectation of price premiums, followed by other reasons. The state targets for certification more than 0.1 million farmers over similar number of hectares by 2010 (Subrahmanyeswari and Chander 2007).

India's National Program for Organic Production (NPOP) requires at least a 2-year conversion period for annual crops before produce may be certified as organically grown. These 2 years pose many challenges because the changes in the chemical, physical, and biological properties of the soil take time to reach an ecological balance. Several experimental transitional studies have reported initial lower yields, followed by yields similar to those of conventional production (Liebhardt et al. 1989; MacRae et al. 1993; Astier, Gersper, and Buchanan 1994). Lower yields in the transition from conventional to organic production are expected, due to lower nutrient concentration and slower release rates of organic materials (Liebhardt et al. 1989; MacRae et al. 1993). Nutrient management is therefore one of the most critical management areas for organic growers. Because synthetic inputs (i.e., chemical fertilizers and pesticides) are disallowed in organic crop production, there is a need for research on organically approved soil amendments and methods for improving soil fertility in organic farming systems, particularly during initial years. Organic fertility inputs such as farmyard manure (FYM) and green manure improve the soil physical properties by lowering bulk density, increasing water-holding capacity, and improving infiltration rates (Werner 1997; Petersen, Drinkwater, and Wagoner 1999; Bulluck et al. 2002; Gopinath et al. 2008). Several studies have shown that organic farming improves soil fertility over time (Drinkwater et al. 1995; Clark et al. 1998; Petersen, Drinkwater, and Wagoner 1999; Fließbach et al. 2007; Saha et al. 2008). These organic systems also lead to greater soil quality and more biological activity in soil than conventionally managed systems (Castillo and Joergensen 2001; Flieβbach et al. 2007; Garcia-Ruiz et al. 2008).

Vegetable farmers in Indian Himalayas routinely apply composted farmyard manure (FYMC) and vermicompost to their soil either alone or in combination with mineral fertilizers, but there is limited research on the effects of these organic amendments on yield and quality of crops and on soil properties, particularly during the period of transition to organic production. We chose to evaluate the impact of different organically approved soil amendments on bell pepper (*Capsicum annuum* L.)–french bean (*Phaseolus vulgaris* L.)–garden pea (*Pisum sativum* L.) system. Emphasis was placed on on-farm inputs or locally produced organic amendments such as FYMC, vermicompost, poultry manure, and biofertilizers in this study. The objectives of the study were to assess the short-term effect of different organic amendments and biofertilizers on (i) productivity and profitability of bell pepper–french bean–garden pea system and (ii) soil properties during a 2-year transition period to organic farming.

Materials and Methods

Experimental Setup and Crop Management

A field experiment was conducted on a silty clay loam soil under irrigated conditions at the Research Farm of Vivekananda Institute of Hill Agriculture (29′ 36′ N, 79° 40′ E, and 1250 m above mean sea level), India during 2005–2007. Before the present experiment, the land had been farmed almost exclusively in a maize–wheat rotation, which included the application of commercial fertilizer and pesticides. Soil samples taken from the surface 15 cm before treatment applications had bulk density of 1.30 Mg m^{-3} (core sampling method), organic carbon (C) content of 1.13% determined as per Walkley and Black (1934), Kjeldahl nitrogen (N) of 403 kg, Olsen phosphorus (P) of 16.2 kg, 1 N ammonium acetate extractable–potassium (K) of 210 kg ha^{-1}, and a pH (1:2.5 soil/water suspension) of 6.8.

The experiment was conducted in fixed plots and included six treatments: T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers [*Rhizobium*/ *Azotobacter* + P solubilizing bacteria (*Pseudomonas striata*)]; T_2, poultry manure (PM) 5 Mg ha^{-1} + biofertilizers (BF); T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated nutrient management (INM) (FYMC 10 Mg ha^{-1} + NPK); and T_6, unamended control. The experiment was laid out in a randomized complete block design with four replications.

Composted FYM and vermicompost were produced on the Research Farm of Vivekananda Institute of Hill Agriculture, India. The FYMC was prepared after cattle dung and bedding material had been composted for 30 days. Residues of soybean (sourced from the organic farming block of the institute) and partially decomposed cattle dung were used in 2:1 ratio (w/w) for vermicomposting. These materials were thoroughly mixed and put into a pit 2 m long × 1.5 m wide× 0.5 m deep. Water was sprinkled to make the material sufficiently wet, and 4000 earthworms (*Eisenia foetida*) were introduced into the pit, which was covered with a jute bag to prevent direct exposure to sunlight. The material in the pit was thoroughly mixed by hand twice, at an interval of 30 days. The compost was removed from the pit after 90 days, and the earthworms were separated with a sieve. Poultry manure was collected from the poultry farm located 2 km away from the research farm. The manure was stored for about 30 days before its application in the field. Composite samples of each amendment were collected 1 week before application to plots and were analyzed for different properties (Table 1). The amounts of nutrients (N–P–K) added in each treatment and crop season are given in Table 2.

All the experimental plots were manually tilled to a depth of 15 cm using a spade in both years. The organic amendments were treated with *Trichoderma viridae* at 2.5 kg ha^{-1}, as a prophylactic measure against soil-borne diseases, then incubated for about 20 days and thoroughly incorporated into the top 15 cm of surface soil before planting each crop. All the organic amendments were applied on a dry-weight basis. Organic amendments were applied by hand 2 weeks before sowing and were incorporated within 24 h of application with a spade. Half the N (50 kg ha^{-1}) and full P (22 kg ha^{-1}) and K (41.5 kg ha^{-1}) were applied at the time of bell pepper transplanting, and the remaining N (50 kg) was top-dressed in two equal splits, 45 and 60 days after planting. However, all the fertilizers (50–30.5–41.5 kg N–P–K ha^{-1} for french bean and 20–26–33.3 kg N–P–K ha^{-1}

Table 1
Moisture and nutrient contents of organic amendments used in the experiment (averaged across six cropping seasons)

		Total nutrient content						
Organic amendment	Moisture (%)	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Fe (g kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})
FYMC	54	10.6	4.6	6.6	4.4	290	54	322
Poultry manure	44	17.1	16.3	8.0	4.6	354	77	402
Vermicompost	52	15.1	6.0	5.7	5.1	128	40	320

Note. FYMC, composted farmyard manure.

Table 2
Amount of nutrients added to each crop (averaged across 2 years)

	Nutrients added (kg ha^{-1})		
Treatment	N	P	K
T_1	212	92	132
T_2	86	82	40
T_3	113	45	43
T_4	155	79	87
T_5			
Bell pepper	206	68	108
French bean	156	77	108
Garden pea	126	72	99
T_6	—	—	—

Notes. T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2, poultry manure (PM) 5 Mg ha^{-1} + BF; T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated nutrient management (FYMC 10 Mg ha^{-1} + NPK); and T_6, unamended control.

for garden pea) were applied at the time of their sowing. The bell pepper (cv. California wonder) seedlings were treated with biofertilizers before transplanting in the plots under different organic amendments. *Azotobacter* and PSB each at 2 kg ha^{-1} were mixed in 50 L water ha^{-1}, and the roots of bell pepper seedlings were dipped in the solution for 30 min and transplanted in the planting geometry of 50 × 50 cm during the third week of April in both 2005 and 2006 in the experimental plots. Seeds of french bean (cv. VL Bauni Bean 1) and garden pea (cv. VL Ageti matar 7) were treated with biofertilizers [*Azotobacter* (french bean) / *Rhizobium leguminosarum* (garden pea) and *Pseudomonas* sp. each at 10 g kg^{-1} seed] before sowing in the plots as per treatment. French bean was sown at a seeding rate of 75 kg ha^{-1} (40 × 10 cm) during the third week of August in both years. Similarly, garden pea was sown at a seeding rate of 100 kg ha^{-1} and a row spacing of 30 cm during the second week of November 2005 and the third week of November 2006. The crops were irrigated as and when required. No chemical insecticides, fungicides, or herbicides were used in keeping with organic standards. Weeds were managed by hand weeding once followed by two hoeings using a manually operated wheel-hoe during each crop season. The crops were not infested by any major insect pests or diseases in both the years. However, azadirachtin [a neem (*Azadirachta indica*)–based formulation] and *Trichoderma viridae* were sprayed three times during each crop season as a prophylactic measure against insect pests and diseases, respectively.

Soil Sampling and Analysis

Soil samples were collected from the surface layer (0–15 cm) of all the plots before treatment applications and immediately after completion of the experiment in May 2007. Five random cores were taken from each plot with a 5-cm diameter tube auger and bulked. Soil samples were air dried and ground to pass through a 2-mm sieve. All soil samples meant for chemical analysis were stored at room temperature until required for analysis. The rest of the soil samples were immediately transferred to the laboratory for analysis of enzyme activities. Soil samples were kept at 4 °C in plastic bags and analyzed within 2 weeks. Bulk density was determined by calculating the soil's dry weight (dried at 110 °C) and volume of the soil sample. The soil pH was determined in 1:2.5 soil/water suspension (Jackson 1962). Oxidizable soil organic C was determined by the method of Walkley and Black (1934), Kjeldahl N was measured with a FOSS Tecator analyzer (Model 2200), and available P was found by the method of Olsen et al. (1954). Available K was determined with 1 N ammonium acetate (NH_4OAc) and flame photometry (Jackson 1962). All chemical results are given as means of triplicate analyses and are expressed on an oven-dry basis. Soil moisture was determined after being dried at 105 °C for 24 h.

Soil dehydrogenase activity was estimated according to Casida, Klein, and Santoro (1964). Soil was incubated with triphenyltetrazolium chloride, and the triphenylformazan absorbance was measured at 485 nm. Urease activity in soil was measured by following the method of Tabatabai and Bremner (1972). Soil samples were incubated with Tris (hydroxymethyl) aminomethane (THAM) buffer (pH 9.0) and urea solution; excess urea was estimated colorimetrically at 527 nm. Acid phosphatase was determined according to Tabatabai and Bremner (1969) after incubating the soil with *p*-nitrophenyl phosphate disodium and measuring the *p*-nitrophenol absorbance at 400 nm. β-Glucosidase activity was estimated by determination of the *p*-nitrophenol released after 1 h of soil incubation with *p*-nitrophenyl-β-D-glucopyranoside (Eivazi and Tabatabai 1977). The amount of *p*-nitrophenol was determined at 400 nm using a spectrophotometer (Tabatabai and Bremner 1969).

Economic Analysis

Economic analysis was based on the prevailing cost of input/operations and price of produce (Table 3). The cost of cultivation involved the expenditure toward land preparation, seed and sowing, organic amendment/mineral fertilizers and their application, pest control, irrigation, and harvesting. The farm gate prices of various inputs were taken for economic analysis. The seed and mineral fertilizer costs were from agro-input retailers. Manure can represent a substantial cost to organic producers and can vary widely depending on transport distances and the costs of obtaining the manure (Archer et al. 2007). However, all the organic amendments did not have market price in the study area and hence the cost was estimated in terms of the labor involved in different activities of composting, loading, and transportation within 2 km of the field. A wage rate of Rs 10 (US $0.21) h^{-1} was used in

Table 3
Parameters used to calculate economics of bell pepper–french bean–garden pea cultivation

	Actual values (Rs)		
Parameter	Bell pepper	French bean	Garden pea
Price of seed	1800 ha^{-1}	10500 ha^{-1}	6400 ha^{-1}
Price of NPK	2230 ha^{-1}	2190 ha^{-1}	1540 ha^{-1}
Price of FYMC	900 Mg^{-1} DW	900 Mg^{-1} DW	900 Mg^{-1} DW
Price of poultry manure	664 Mg^{-1} DW	664 Mg^{-1} DW	664 Mg^{-1} DW
Price of vermicompost	3067 Mg^{-1} DW	3067 Mg^{-1} DW	3067 Mg^{-1} DW
Labor cost for planting	2000 ha^{-1}	2000 ha^{-1}	2000 ha^{-1}
Labor cost for fertilizer application	400 ha^{-1}	400 ha^{-1}	400 ha^{-1}
Labor cost for manure spreading and incorporation	200 Mg^{-1} DW	200 Mg^{-1} DW	200 Mg^{-1} DW
Price of produce	15000 Mg^{-1}	25000 Mg^{-1}	15000 Mg^{-1}

Notes. FYMC, composted farmyard manure; DW, dry-weight basis; 1 US \$ = Rs 46.5.

calculating labor costs. A price premium ranging from 10 to 100% greater than that for conventional produce is already being realized in many organically produced crops including bell pepper in India (Chadha and Choudhary 2007). Therefore, economic evaluation of organic vegetable cultivation was also done by assuming different price premiums for the produce to assess whether these vegetables can be profitably grown under organic farming conditions in comparison with integrated nutrient management (INM).

Statistical Analysis

All of the soil and plant data were analyzed using Duncan's multiple-range tests (Duncan 1955) at the $P < 0.05$ level. Differences between mean values were evaluated by a one-way analysis of variance (ANOVA) (SPSS version 10.0; SPSS, Chicago, Ill.).

Results and Discussion

Crop Productivity

There were significant differences among treatments with respect to bell pepper yield in both years (Table 4). In general, the bell pepper yield under all the treatments except unamended control was greater in 2006 than in 2005. Integrated nutrient management produced significantly greater fruit yield than all other treatments in both years. Russo and Taylor (2006) reported that in the first year, bell pepper yields for the plants in the transition plots were lower than for the plants in the conventional production. In contrast, Chellemi and Rosskopf (2004) reported that organic pepper yields from soil-solarized plots were similar to yields obtained by conventional farmers using great inputs of rapidly mobile N sources. In our study, the yield reduction under the best organic treatment (T_1) compared to INM was 33.1% in 2005 and 18% in 2006. Among the treatments involving organic amendments, T_1 and T_4 being at par gave significantly greater fruit yield than other treatments.

Table 4
Effect of treatments on yields (t ha^{-1}) of bell pepper, french bean, and garden pea

	Bell pepper		French bean		Garden pea	
Treatment	2005	2006	2005	2006	2005–6	2006–7
T_1	23.61b	32.30b	3.33c	3.62c	6.72a	7.35a
T_2	18.14c	25.96c	3.14c	3.17d	5.76b	6.45b
T_3	16.70c	23.73c	2.89d	3.01d	5.06c	6.06b
T_4	21.92b	30.44b	3.80b	3.94b	7.02a	7.52a
T_5	35.33a	39.47a	5.13a	5.85a	6.99a	7.16a
T_6	8.84d	6.55d	1.74e	1.21e	2.99d	1.41c

Notes. T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2, poultry manure (PM) 5 Mg ha^{-1} + BF; T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated nutrient management (FYMC 10 Mg ha^{-1} + NPK); and T_6, unamended control. Means in the same column with different letters are significantly ($P < 0.05$) different.

In french bean, INM produced significantly greater pod yield than all other treatments in both years (Table 4). Among the organic treatments, T_4 gave the greatest pod yields (3.80 and 3.94 t ha^{-1}) and was significantly superior to other treatments in both the years. Application of FYMC (T_1) was the next best treatment, whereas T_3 produced the lowest pod yield. The yield reduction under the best organic treatment (T_4) compared to INM was 26% in 2005 and 33% in 2006.

Lower yields of both bell pepper and french bean in the plots amended with organic manures and composts may have been associated with the less readily available nutrients in the initial years of conversion (Table 5), as nutrient cycling processes in first-year organic systems change from inorganic N fertilization to organic amendments (Harris et al. 1994; Reider et al. 2000) and slower release rates of organic materials (Liebhardt et al. 1989; MacRae et al. 1993). Soil fertility in organic production systems is controlled by organic amendments, such as FYMC, vermicompost, and poultry manure used in this study. Nitrogen availability in particular is maintained through the synchronization across space and time of net N mineralization from soil, organic N pools, and plant uptake of inorganic N. This process depends on the constant renewal of biologically available N to soil organic N pools (Delate and Cambardella 2004).

In garden pea, however, T_4 produced the greatest pod yields (7.02 and 7.52 t ha^{-1}) and was significantly superior to other treatments except T_5 and T_1 (Table 4). Increase in green pod yield may be attributed to better availability of nutrients, particularly P and K, to the crop and improved soil bulk density (Table 5). The results obtained here are in agreement with those of Pandey et al. (2006). Application of PM (T_2) produced about 10% greater pod yield than did T_3. This might be due to greater P input (82 kg ha^{-1}) through PM than VC (45 kg ha^{-1}), as the P requirement of garden pea is greater (26 kg ha^{-1}) compared to N and K.

Soil Properties

The soil bulk density was reduced significantly in all the treatments compared to the control (Table 5). Application of FYMC (T_1) resulted in the lowest bulk density (1.19 Mg m^{-3}),

Table 5
Effects of different treatments on soil properties after 2 years

Treatment	BD (Mg m^{-3})	pH	Organic C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	1.19c	7.1a	1.30a	446b	23.4a	252a
T_2	1.26b	6.9bc	1.16bc	432bc	21.2b	239b
T_3	1.22bc	6.9bc	1.22ab	430c	20.5b	237b
T_4	1.20c	7.0ab	1.27ab	441bc	23.5a	256a
T_5	1.22bc	6.9bc	1.21ab	492a	24.4a	259a
T_6	1.33a	6.8c	1.06c	409d	18.7c	215c

Notes. T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2, poultry manure (PM) 5 Mg ha^{-1} + BF; T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated nutrient management (FYMC 10 Mg ha^{-1} + NPK); and T_6, unamended control; BD, bulk density. Means in the same column with different letters are significantly ($P < 0.05$) different.

closely followed by T_4. The use of organic amendments has been associated with many desirable soil properties including lowering of bulk density (Werner 1997; Petersen, Drinkwater, and Wagoner 1999; Bulluck et al. 2002; Gopinath et al. 2008). The soil pH increased in all the treatments compared to control. Our results are consistent with earlier reports (Drinkwater et al. 1995; Werner 1997; Clark et al. 1998; Gopinath et al. 2008) where organic systems had greater pH levels in mildly acidic soils than their conventional counterparts. This illustrates the important role organic amendments and other organic matter inputs can have in buffering the soil (Stroo and Alexander 1986; Arden-Clarke and Hodges 1988). Similarly to pH, soil organic C was also significantly greater in all the treatments except T_2 compared to control. Application of FYMC (T_1) resulted in the greatest soil organic C (1.30%) closely followed by T_4. During the transition years from conventional to organic farming systems, soils show a very slow but important increase in organic matter (Kuo, Sainju, and Jellum 1997; Clark et al. 1998). An important feature of environmental benefit due to a change in agricultural practice is the soil C content (Carter et al. 1997). Depending on soil type, climate, management, and the capacity of a soil to store organic matter, SOC levels may increase linearly with the amount of organic matter input (Carter 2002).

Plots under INM, however, had significantly greater levels of available N than those under organic amendments (Table 5). Lower availability of plant nutrients in plots under organic amendments was expected due to the slower release rates of N from organic manures (Brusko 1989; Liebhardt et al. 1989; MacRae et al. 1993). Plots under INM being at par with T_4 and T_1 plots had significantly greater levels of available P and K than other treatments. Clark et al. (1998) and Reganold et al. (1993) also observed an increase in available K in the organic and low-input systems.

The incorporation of organic amendments to soil influences soil enzymatic activities because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil (Pascual et al. 1998). A significant increase in dehydrogenase activity occurred in the plots amended with FYMC (T_1) (Figure 1A). This maximum activity might be linked to more substrate availability in FYM-amended plots. Organic amendments can foster beneficial microorganisms, which in turn facilitates soil enzymatic activities (Doran, Sarrantonio, and Liebig 1996; Drinkwater et al. 1995). Being

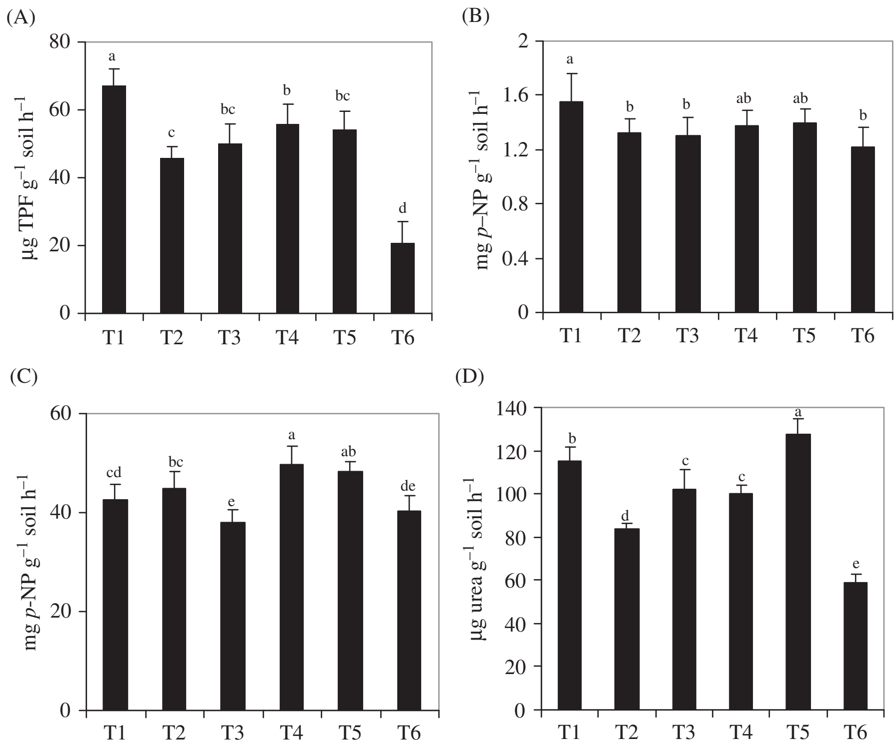

Figure 1. Effect of organic amendments on soil dehydrogenase (A), acid phosphatase (B), β-glucosidase (C), and urease (D) activities. Bars with different letters within each panel are significantly ($P < 0.05$) different.

the substrate for microbial activity, soil organic matter plays an important role in protecting soil enzymes, which become immobilized in a three-dimensional network of clay and humus complexes (Tabatabai 1994). This reflects the greater biological activity in these plots and the stabilization of extracellular enzymes through complexation with humic substances (Burns 1982; Colvan, Syers, and O'Donnell 2001). The dehydrogenase activity was also greater in T_4, T_5, and T_3 plots compared to other treatments. Similarly, changes in soil phosphatase activities, which play an essential role in the mineralization of organic phosphorus, were also observed among organically amended treatments. The acid phosphatase activity was greater in T_1 plots and was lowest in T_3 and T_6 plots (Figure 1B). T_4 plots had the greatest β-glucosidase activity, closely followed by T_5 (Figure 1C). Application of VC (T_3) resulted in lower β-glucosidase activity compared to other treatments. The urease activity was greatest in the plots under INM compared to other treatments (Figure 1D). It has been reported that urease activity is positively correlated with N content of soil (Frankenberger and Dick 1983). Among the organic treatments, FYMC-amended plots (T_1) had the greatest urease activity, followed by plots treated with VC (T_3). Similar results were observed in our earlier study (Saha et al. 2008).

Economics of Organic Crop Production

In general, the cost of bell pepper cultivation was greater with the use of different organic amendments, except PM 5 t ha^{-1} + BF compared to INM (Table 6). It was greatest

Table 6

Effect of treatments on cost of cultivation and gross margin (000 Rs ha^{-1}) from bell pepper–french bean–garden pea system (mean data of 2 years)

Treatment	Bell pepper			French bean			Garden pea			System gross margin
	Cost of cultivation	Gross margin	B/C ratio	Cost of cultivation	Gross margin	B/C ratio	Cost of cultivation	Gross margin	B/C ratio	
T_1	47.0	329.5	8.0	53.9	33.1	1.6	51.9	53.6	2.0	416.2
T_2	29.4	267.6	10.1	37.5	41.5	2.1	35.2	56.4	2.6	365.5
T_3	48.8	224.2	5.6	63.6	10.2	1.2	62.4	21.0	1.3	255.4
T_4	41.7	310.8	8.4	51.0	45.8	1.9	49.9	59.1	2.2	415.7
T_5	39.7	464.3	12.7	47.0	90.3	2.9	42.8	63.3	2.5	617.9
T_6	22.5	81.0	4.6	31.8	5.2	1.2	26.4	6.6	1.2	92.8

Notes. T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2, poultry manure (PM) 5 Mg ha^{-1} + BF; T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated nutrient management (FYMC 10 Mg ha^{-1} + NPK); and T_6, unamended control.

(Rs 48880 or US \$1051.1 ha^{-1}) with T_3 due to greater input cost of VC (Rs 2000 or US \$43.01 t^{-1}). Archer et al. (2007) also reported that manure can represent a substantial cost to organic producers and can vary widely depending on transport distances and the costs of obtaining the manure. T_5 gave the greatest gross margin and B/C ratio compared to other treatments. Among the organic treatments, T_1 gave the greatest gross margin compared to other treatments. However, T_2 gave the greatest B/C ratio due mainly to low input cost of PM. Gopinath et al. (2009) have reported that at least 40% price premium for organic bell pepper may be required to offset the greater cost of cultivation and low yields under organic production system compared with INM. Russo and Taylor (2006) also reported that if a price premium is assigned to the value of organically grown bell pepper then the costs of production could be mitigated.

The cost of french bean cultivation was greater with T_3 followed by T_1 (Table 6). T_5gave the greatest gross margin and B:C ratio compared to other treatments. Among the organic treatments, T_4 gave greater gross margin, but greater B/C ratio was recorded with T_3. The gross margin from T_5 was greater compared to other treatments even when 40% price premium (Rs 35 or US \$0.75 kg^{-1}) was assumed for organic bell pepper (Figure 2A). However, at 60% price premium for organic french bean, T_4 was greater compared to T_5. Therefore, organic french bean cultivation may not be as profitable as that grown with integrated crop management practices during the transition period, when no price premium is available for the produce. Furthermore, at least 45% price premium for organic french bean may be required to offset the greater cost of cultivation and poor yields under an organic production system compared with integrated crop management.

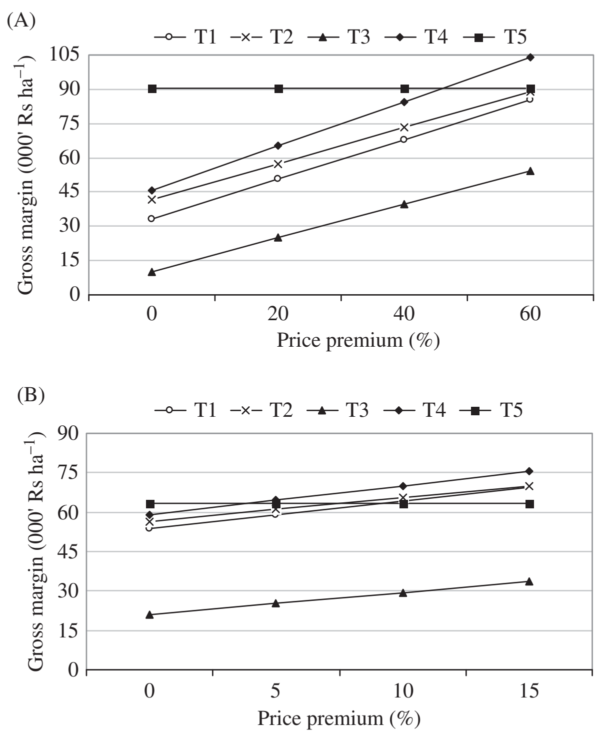

Figure 2. Gross margin at different price premiums for organic french bean (A) and organic garden pea (B) grown with different organic amendments.

The cost of garden pea cultivation was also greatest with T_3 and lowest with T_2, due to variable input quantities and costs. T_5 gave greater gross margin compared to other treatments. Among the organic treatments, greater gross margin was recorded with T_4 closely followed by T_2. The latter treatment also gave greater B/C ratio (2.6) than other treatments. T_4 gave slightly greater gross margin than T_5 when 5% price premium (Rs 15.75 or US \$0.34 kg^{-1}) was assumed for organic garden pea (Figure 2B). At 10% price premium for organic garden pea, T_2 also gave greater gross margin, whereas T_1 gave a similar gross margin as that of T_5. At 15% price premium for organic garden pea, all the treatments except T_3 gave 10–19% greater gross margin than INM. Therefore, at least 5% price premium for organic garden pea may be required to offset the greater cost of cultivation under organic production system compared with integrated crop management.

Conclusions

Research-based recommendations must be developed for suitable organic amendments that provide great yields and adequate soil fertility during the transition to organic production. The comparison of different organic amendments such as FYMC, PM, VC, and combined application of organic amendments, along with biofertilizers, revealed the yields of bell pepper and french bean under organic nutrient management were markedly lower (25.2–45.9% and 29.5–46.2%, respectively) than with INM. Garden pea, however, performed better under organic management and gave about 3% greater yield under T_4 plots compared with INM. We conclude that the farmers have the option to choose either T_1 or T_4 for quick stabilization of soil fertility as well as biological activity, which in turn help in nutrient availability and reduce loss in yield during a 2-year transition period. However, some price premiums (5% for garden pea, and 40% for bell pepper and french bean) may be required to offset the greater cost of cultivation and poor yields under organic production systems.

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